Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

VOLUME XXIII NUMBER 7

THE

JOURNAL OF GEOLOGY

OCTOBER-NOVEMBER 1915

REVISION OF PRE-CAMBRIAN CLASSIFICATION IN ONTARIO[1]

WILLET G. MILLER AND CYRIL W. KNIGHT
Ontario Geological Survey, Toronto, Canada

The pre-Cambrian rocks of Ontario have undergone much scrutiny during the last seventy years. At the very beginning of his labors as provincial geologist of Canada (Ontario and Quebec) in 1843 Logan confirmed the observations made by other investigators, that the oldest fossiliferous rocks lie unconformably on a vast crystalline series. By degrees he and his associates, working in the regions adjacent to the Ottawa River and to the north shore of Lake Huron respectively, came to the conclusion that these ancient rocks as regards their age relations are divisible into two great groups, the older of which was named the Laurentian and the younger the Huronian.[2] Other pre-Cambrian rocks were studied on Lake Superior.[3] To these was given the name Upper Copper-bearing Rocks of Lake Superior. They were divided into two groups, the upper of which has come to be known as the Keweenawan and the lower as the Animikie.

---

[1] This paper was presented in abstract at the meeting of the Geological Society of America, December, 1914.

[2] *American Association for the Advancement of Science*, 1857; *Geology of Canada*, 1863, pp. 22 f.

[3] *Geology of Canada*, 1863, pp. 67 f.

In conformity with the views of the time, Logan and his associates considered the Laurentian to be made up essentially of metamorphosed sedimentary material. With the passing of the years, the Laurentian came to be looked upon as separable into three groups: (1) Lower Laurentian or Ottawa series, consisting essentially of granite gneiss; (2) Middle Laurentian or Grenville series, consisting of crystalline limestone and other rocks; and (3) Upper Laurentian or Norian. From the Laurentian groups was first taken the Upper Laurentian, which was proved to be not of sedimentary origin but an intrusive.[1] Afterward the Grenville

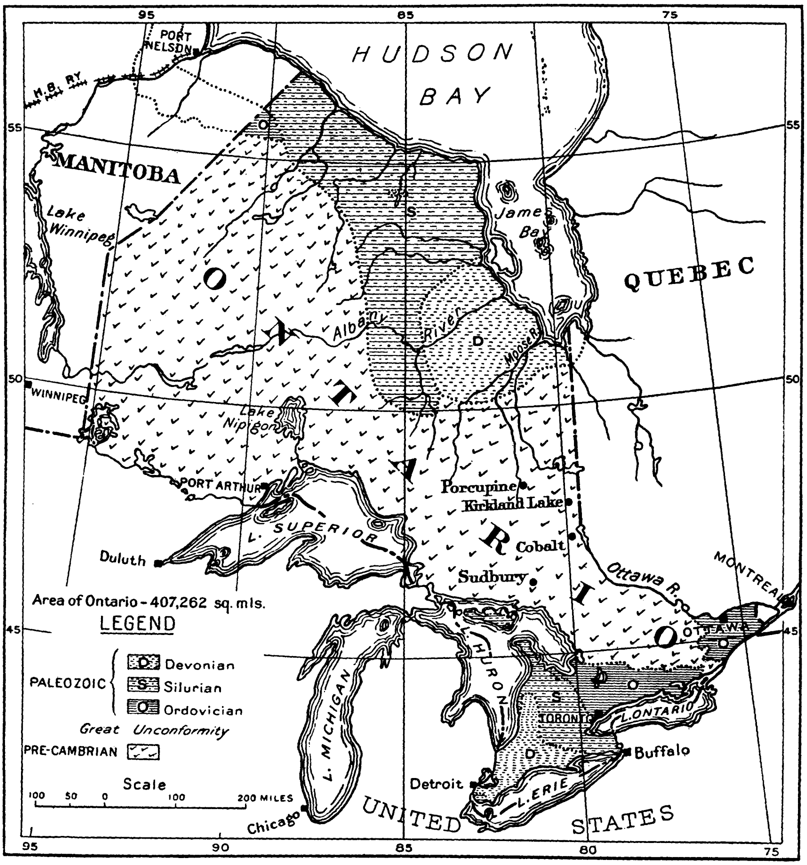

FIG. 1.—Geological sketch map of Ontario

was taken away and the name Laurentian came to stand only for granite and gneiss of undoubted igneous origin, older than the so-called Huronian sediments.[1]

---

[1] *Neues Jahrb.*, Beilage Band 8, 1893, pp. 419–98.

CLASSIFICATIONS NOW IN USE

The need for a revision of the classification and nomenclature of the pre-Cambrian rocks has been felt from time to time as knowledge concerning them has increased.

Table I shows the classification that has been adopted by the authors.[2] Like all other classifications it will be subject to revision when a more perfect understanding of the relations of the rocks is acquired.

In Table II are given the classifications employed by several other authors.

LAURENTIAN AND HURONIAN

Logan, himself, when introducing the names Laurentian and Huronian said: "These local names are, of course, only provisional, devised for the purpose of avoiding paraphrastic or descriptive titles, the use of which had been found inconvenient, and they can be changed when more important developments, proved to be the equivalents of the series, are met with elsewhere."[3] Hence, when it is found advisable to change the classification or to discard the now historic names, looked on by Logan as being only provisional, mere sentiment should not be permitted to stand in the way. In most cases it is better to discard a name rather than employ it in a new sense.

As shown in a preceding paragraph, the term Laurentian is now used in a much-restricted sense and, as will be seen from the following pages, different meanings are attached to it by various authors. The earlier literature in which Laurentian rocks were described has become almost unintelligible.

Much confusion has arisen also through the employment of the classic name Huronian, especially with the prefixes Upper, Middle, and Lower, in different senses. The term Lower Huronian, for example, has been applied indiscriminately to certain rocks that lie below one of the greatest known unconformities, that between the Timiskamian and Animikean of our classification, as well as to those above it. Again, rocks have been classed as Upper Huronian, or Animikie, which have not been proved to be

---

[1] Report of International Committee, *Jour. Geol.*, February-March, 1905.

[2] *Ont. Bur. Mines*, XXII, Part II, Appendix.

[3] *American Association for the Advancement of Science*, 1857.

TABLE I

Pre-Cambrian

Keweenawan	
Unconformity	
Animikean	Under this heading the authors place not only the rocks that have heretofore been called Animikie, but the so-called Huronian rocks of the "classic" Lake Huron area, and the Cobalt and Ramsay Lake series. Minor unconformities occur within the Animikean.
Great unconformity	
(Algoman granite and gneiss) *Igneous contact*	Laurentian of some authors, and the Lorrain granite of Cobalt, and the Killarney granite of Lake Huron, etc.
Timiskamian	In this group the authors place sedimentary rocks of various localities, that heretofore have been called Huronian, and the Sudbury series of Coleman.
Great unconformity	There is no evidence that this unconformity is of lesser magnitude than that beneath the Animikean.
(Laurentian granite and gneiss) *Igneous contact*	
Loganian: Grenville (*Sedimentary*) Keewatin (*Igneous*)	The authors have found the Keewatin to occur in considerable volume in southeastern Ontario and have determined the relations of the Grenville to it.

different in age from certain so-called Lower and Middle Huronian. It may be added that for many years the Keewatin also was called Lower Huronian. Even at the present time when making use of the name Huronian, in order to secure clearness, it is necessary to say in what sense the name is employed, whether in that of the United States Geological Survey or in that of Coleman or Lawson *et al.* Owing to the confusion that has arisen in connection with the use of the term the authors think it well to discard it.

Among those, including Coleman, Collins, and the authors, who have studied during recent years the pre-Cambrian rocks of the Lake Huron–Lake Timiskaming region, there is agreement as to most of the age relations, as will be seen from the classifications on a following page, but different nomenclatures are employed.

As to facts, the chief difference in opinion between Coleman and the authors is in regard to the relations among what he calls the Lower and Upper Huronian and the Animikie, and what we call collectively the Animikean. It is agreed that the Cobalt series, the Ramsay Lake series of Sudbury, and the usually flat-lying sediments of the classic area of Lake Huron are of the same age. But in Coleman's opinion, as shown in his table, the sediments of the Sudbury basin, the so-called Animikie series, are younger than the Ramsay Lake series, which he classes as Lower Huronian. But no discordance has been proved to exist between the Ramsay Lake series and the Animikie of the near-by Sudbury basin. For this and other reasons the authors class the Ramsay Lake series and the Animikie together as the Animikean. In this they are supported by investigations made by Van Hise and Seaman, who say: "About half a mile east of Sudbury they found a breccia or conglomerate [Ramsay Lake series] similar in every way to that seen at Onaping [Animikie series of Sudbury basin] resting on the eroded edges of Huronian [Timiskamian] and containing fragments of it."[1]

Beginning with the bottom of the columns of the two classifications, it will be seen that Coleman has accepted, provisionally at least, our interpretation of the relations of the Keewatin and the Grenville, described in a recent report.[2]

As is shown by Table II, Coleman and Collins use the name Sudbury series or Sudburian for the rocks which we call Timiskamian. But Timiskamian has priority as it was employed by the Ontario Bureau of Mines for rocks that occur at various points over an area at least 5,000 square miles in extent before the term "Sudburian" was introduced.[3] Moreover, since Logan first studied his "Huronian" rocks on Lake Timiskaming, the name Timiskamian is appropriate for a part of them. Further, the name Sudburian is likely to be confused with sudburite, a name applied to certain basic igneous rocks at Sudbury that intrude the Timiskamian but are older than the Algoman granite and gneiss.[1] It may be added that basic rocks of the age of sudburite are widespread and have frequently been mistaken for Keewatin. They are represented by the peridotite and augite lamprophyre of the Porcupine region, one hundred miles north of Sudbury, and by the lamprophyres and other rocks of Cobalt, ninety miles to the northeast of Sudbury. For economic purposes, at least, some age name should probably be applied to these basic rocks. Sudburian would be suitable had it not been used in another sense.

---

[1] *U.S. Geol. Survey Bull.* 360, p. 425.

[2] *Ont. Bur. Mines*, XXII, Part II.

[3] *Eng. and Min. Jour.*, September 30, 1911, p. 648.

While Coleman and the authors are agreed on the age relations of the two great series of granites and gneisses, different nomenclatures are employed. The rocks that he calls "Granites Eruptive through the Keewatin," and to which he gives no distinctive age name, we class as Laurentian. In his classification Laurentian is applied to the granites and gneisses that we, following Lawson's nomenclature, class as Algoman.

The appellation Laurentian was first given to the rocks of the district bordering the Lower Ottawa River, and the older granites and gneisses here are different in age from the Algoman. The fact that the rocks now called Algoman have frequently been classed as Laurentian should not be given consideration. If the name Laurentian is to be retained, it should be applied to the oldest granites and gneisses. The following quotation shows that Logan did not intend that the name should be applied to granites that are intrusive into any part of his "Huronian." Further, it will be seen that, in the classic area of Lake Huron, Logan recognized both the Laurentian which, in his opinion, underlies all of his Huronian sediments, including that part of them now known as Timiskamian, and granites eruptive into the Huronian. Unfortunately later work has shown that much, at least, of what he considered to be Laurentian is really the intrusive granite which he called Huronian granite.

[1] *Ont. Bur. Mines*, XXIII, 215–17.

> The intrusive granite occupies a considerable area on the coast of Lake Huron, south of Lake Pakokagaming. It there breaks through and disturbs the gneiss of the Laurentian series and forms a nucleus from which emanates a complexity of dykes, proceeding to considerable distances. As dykes of a similar character are met with intersecting the rocks of the Huronian series [Timiskamian], the nucleus in question is supposed to be of the Huronian age, as well as the greenstone dykes which are intersected by it.[1]

If Logan mistakenly applied the name Laurentian to his "Huronian granite" in certain areas, why should his mistake be perpetuated? Now that we know these granites and gneisses in some localities belong to what he called Huronian granite, why should we apply the name Laurentian to them instead of to the group that is much older, the Laurentian of our classification and the "Granites Eruptive through the Keewatin" of Coleman's?

There are certain objections to giving the names of systems or series to intrusives such as the Laurentian and Algoman. For this reason the authors prefer to inclose the names in parentheses in the table of classification, thus: (Laurentian intrusives) and (Algoman intrusives), or (Laurentian) and (Algoman). These intrusives occur in such great volume in the pre-Cambrian that it would seem well to retain distinctive age names for them. Age names are especially useful in economic work, our most important gold deposits, for example, being genetically connected with the Algoman.

DUAL SUBDIVISION

A dual subdivision of the pre-Cambrian, as shown in Table II, is employed by many authors. It is purely arbitrary, and is now known to be based on a misconception as to the relations of the rocks. It was believed, or assumed, that the greatest unconformity within the pre-Cambrian is that at the base of the "Lower Huronian," as the term is used by the U.S. Geological Survey. Such, however, has not proved to be the case. There is no proof that the unconformity at the base of the Timiskamian is of less magnitude than that at the base of the Animikean, of the authors' classification, or vice versa. According to Coleman, the various sedimentary series of the Timiskamian, his Sudbury series, where

---

[1] *Geology of Canada*, 1863, p. 58.

TABLE II

Age Classifications of Pre-Cambrian Rocks of Ontario Proposed by Various Authors

Miller and Knight*	Coleman†		Collins‡		Lawson§		*U.S. Geol. Survey Bull. 360*‖	
Keweenawan	Post Laurentian	Keweenawan	Huronian	Keweenawan	Algonkian	Keweenawan (Nipigon)	Algonkian	Keweenawan
Unconformity		*Unconformity*		*Unconformity*		*Unconformity*		*Unconformity*
Animikean (with minor unconformities)		Animikie *Unconformity* Upper Huronian *Small unconformity* Lower Huronian		Whitewater Lorrain *Local unconformity* Cobalt		Animikie		Upper Huronian *Unconformity* Middle Huronian *Unconformity* Lower Huronian
Great unconformity		*Great unconformity*		*Great unconformity*		*Eparchean interval*		*Unconformity*
(Algoman Intrusives)		(Laurentian, in eruptive contact with lower rocks)	Pre-Huronian	Batholithic granite intrusives	Archean	Algoman (granite-gneiss, batholithic in Huronian)		
Intrusive contact				*Intrusive contact*		*Irruptive contact*		
Timiskamian	Pre-Laurentian	Sudbury		Sudbury, Timiskaming, etc.		Upper Huronian *Unconformity* Lower Huronian		
Great unconformity		*Great unconformity*		*Unconformity*		*Unconformity*		
(Laurentian Intrusives)		(Granites eruptive through the Keewatin)		Granite intrusives		Laurentian (granite-gneiss, batholithic in Ontarian)	Archean	Laurentian
						Irruptive contact		
Loganian: Grenville (*Sedimentary*) Keewatin (*Igneous*)		Keewatin, probably equivalent of Grenville		Keewatin group		Ontarian: Keewatin Couchiching		Keewatin

---

* *Ont. Bur. Mines*, XXII, Part II, Appendix.

† *Ibid.*, XXIII, Part I, p. 206.

‡ *Compte-Rendu, 12th Int. Geol. Congress*, p. 403.

§ *Ibid.*, p. 351.

‖ Pp. 42 and 43.

most fully developed, appear to have an approximate aggregate thickness of 29,000 feet.[1] Elsewhere these sediments are also known to have great thickness.

The term "Eparchean Interval," concerning which there has been so much discussion in the past, should now be discarded. The so-called Lower and Middle Huronian rocks of the classic area of Lake Huron lie above and not beneath it. There are now known to be two great "intervals" in the pre-Cambrian, that beneath our Animikean and that beneath our Timiskamian, and not merely one as has been assumed.

Moreover, a dual subdivision of the pre-Cambrian cannot be justified on the basis of differences in metamorphism or other characteristics of the rocks. Normally there is a gradual increase in degree of metamorphism from the youngest to the oldest. In the province of Ontario the Animikean rocks are only slightly metamorphosed or disturbed, while the Timiskamian are disturbed and frequently rendered schistose, and the Loganian are highly metamorphosed.

Sediments, Grenville, occur in great volume in the Loganian. Hence the "Archean" cannot be said to be essentially igneous, as assumed at one time. Moreover, ordinary stratigraphic methods, which have been cited as a test as to whether certain groups of rocks should be classed as Archean or otherwise, can be applied in studying the Grenville. This has been shown by the authors' work in southeastern Ontario.[2]

Briefly, it may be said that the discovery of the true relations of the Timiskamian destroys the argument for a dual classification of the pre-Cambrian.

COMMENTS ON TABLES I AND II

The name Keweenawan in the tables is employed in the sense in which it has been used by most writers on the pre-Cambrian of North America. Certain greenstones in the Lake Huron area were classed by Logan as intrusives of Huronian age. They have come to be known as the "Thessalon greenstones," after the name of the near-by town, and during the last decade they have been frequently referred to in literature and classed as of Keewatin age. In the summer of 1914, however, the junior author was able to verify Logan's conclusion regarding their age, and to prove that they are in intrusive contact with the Animikean, as defined in Table I. Hence they are classed as Keweenawan.

---

[1] *Ont. Bur. Mines*, XXIII, 214.

[2] *Ibid.*, XXII, Part II, pp. 41 f.

The group name Animikean is explained in a preceding paragraph as well as in Table I. In addition to what has long been called the Animikie, it includes the usually flat-lying sediments of Lake Huron, which have been classed as Lower and Middle Huronian by various authors. There is an unconformity within these sediments but we do not think it is of the magnitude that it has been inferred to be. It is to be described in a forthcoming paper.[1] We look on this unconformity as being similar to those which have been observed in the Cobalt series. As already said, the flat-lying sediments of Lake Huron, the Ramsay Lake series of Sudbury, and the Cobalt series, all being of post-Algoman age and no discordance having been proved to exist between them and the Animikie, are classed by us with the latter rocks under the name Animikean. It may be added that the quartzites and jasper conglomerates of the upper part of the Lake Huron series resemble rather closely the upper part of the Cobalt series. As shown in Table II, Collins applies the local name Whitewater series to the sedimentary rocks of the Sudbury Nickel Basin. The name was given, however, by Nickles and Foerste in 1905 to a part of the Richmond.[2] Hence, it should not be employed for the Sudbury rocks. The name Fabre, which has been used by certain authors as synonymous with Sudbury or Timiskaming, should also be discarded, since the rocks to which the name was applied are merely part of the Cobalt series.[3]

The name Algoman was introduced by A. C. Lawson in 1913.[4] The authors, having found, in the areas examined by them, that granite and gneiss of post-Timiskamian and pre-Animikean age are of wide extent, had employed local names to designate these rocks. At Cobalt the granite was called Lorrain and in southeastern

[1] *Ont. Bur. Mines*, XXIV.

[2] *U.S. Geol. Survey, Professional Paper* 71, p. 172.

[3] *Ont. Bur. Mines*, XIX, Part II, p. 62.

[4] *Compte-Rendu, 12th Int. Geol. Congress*, pp. 359–61.

Ontario, Moira, while other writers had given the name Killarney to the granite that occurs along the north shore of Lake Huron. Algoman now being preferred, although not having priority, the other names may be discarded or used locally.

Basic rocks, of pre-Algoman and post-Timiskamian age, described in a preceding paragraph, are widespread, but no age name is given to them in the tables.

The age relations of the Timiskamian rocks have already been described, and reasons have been given for preferring the use of this name to the other that has been proposed for them.

On a preceding page reasons have been advanced for applying the name Laurentian to the pre-Timiskamian granites and gneisses and not to those of post-Timiskamian age.

The authors agree with Lawson that the Keewatin and the Grenville, or Couchiching, should be grouped together. Ontarian, however, should not be employed as the name of a pre-Cambrian group, since the New York State geologists have long used the term Ontaric (or Ontario) as synonymous with Siluric. Recognizing the objection to Lawson's use of the term, we have substituted for it the name Loganian, as shown in Table II.[1]

According to the views of the authors, the relations between the Keewatin and the Grenville are as follows: The Keewatin rocks represent, for the most part, submarine lava flows. On the surface of these flows are deposited the Grenville sediments. Moreover, it is believed that, while the major part of the Grenville is later than the major part of the Keewatin, a minor part of one group is contemporaneous with a minor part of the other. Hence the two groups, volcanic and sedimentary respectively, are placed in the authors' classification under one age term, the Loganian. Lawson's Couchiching, it seems to the authors, should be correlated with the base of the Grenville, and, since Grenville is the older term, we prefer to discard Couchiching or use it only locally.

That part of the Loganian known as the Grenville is found in much greater volume in southeastern Ontario and the adjacent part of Quebec than in the northern and northwestern parts of the province. This is apparently chiefly due to less erosion having taken place, especially prior to Timiskamian time, in the southeastern section than in the others. Over the northern and northwestern areas the Grenville was eroded until only comparatively small remnants in most localities were left. Later erosion, and intrusions, especially the Algoman, have also assisted in destroying the Grenville. However, the broader, more extensive areas of the series in the southeast can be connected, by tracing outliers from point to point, with the exposures in the north and northwest, where occur Timiskamian and Animikean rocks.

---

[1] *Ont. Bur. Mines*, XXII, Part II, Appendix.

Coleman has described a comparatively large area of Grenville rocks, seven or eight miles southeast of the town of Sudbury, whose relations to the Timiskamian, his Sudbury series, he has determined.[1] The Grenville here consists of cyrstalline limestone, quartzite, and various schists and gneisses, while the Timiskamian contains quartzites, greywackes, and other sediments. The Grenville series is profoundly metamorphosed. The Timiskamian, on the other hand, while often schistose and resting in highly inclined positions, has suffered much less metamorphism than the Grenville. There can be no doubt that the two series near Sudbury are separated by a great discordance and that the Grenville is vastly older than the Timiskamian. Similar relationships are found in other localities in most of which the Grenville is represented by only very small outliers.

Near the eastern end of Lake Kipawa, Quebec, which lies not far distant from the foot of Lake Timiskaming, there is an area of Grenville, consisting of crystalline limestone and other sediments. These rocks, described by the senior author in 1901, have been much disturbed by an intrusion of granite, apparently of the same age as that of Lake Timiskaming, on the eroded surface of which lie the fragmental rocks of the Cobalt series, Animikean.[2]

It would thus seem that the authors are justified in correlating the rocks of southeastern Ontario with those to the north and northwest. They have no doubt as to the relations of the Grenville to the Keewatin which occurs in large volume in the southeastern part of the province as well as in the north and northwest. In the southeastern section there is also a series, the Hastings, that is believed to represent the Timiskamian of the north.[1]

---

[1] *Ont. Bur. Mines*, XXIII, 208–9.

[2] *Am. Geologist*, January, 1901; *Ont. Bur. Mines*, XIII, 102.

METALLOGENETIC NOTES

During the last decade, owing to the great progress that has been made in the production of metals in Ontario, special facilities have been provided for the study of pre-Cambrian rocks. Our information has been much increased concerning the age relations not only of the rocks that represent various epochs of this great period but also of the ore deposits that are associated with them. Of no other part of the continent, or of the world, has the pre-Cambrian proved to be of greater economic interest. The province not only has the world's greatest deposits of nickel, among which have been developed mines that compare favorably in economic importance with those of any other metal found elsewhere, but the gold mines and the cobalt-silver areas are recognized as being among the greatest known.

From Table III it will be seen that there were at least four great metallogenetic epochs during the pre-Cambrian period in Ontario—Grenville, Algoman, Animikean, and Keweenawan. A fifth epoch of minor importance should probably be added to represent the ore bodies associated with the basic intrusives that preceded the intrusion of the Algoman granite and followed the deposition of the Timiskamian sediments. There is proof that many important ore deposits have been removed by erosion, and it seems not unlikely that the rocks of certain epochs, not now productive, contained deposits which have disappeared through the removal of vast thicknesses of material.

SEQUENCE OF INTRUSION AND METAL DEPOSITION

Table III brings out an interesting alternation of intrusion and sedimentation, and the importance of the igneous rocks in the formation of ore deposits. It will be seen that there are broadly five great epochs of igneous activity, basic and acid rocks alternating, viz.: (1) Keewatin, basic; (2) Laurentian, acidic; (3) pre-Algoman, basic; (4) Algoman, acidic; (5) Keweenawan, basic, passing in places into a considerable volume of acidic varieties. The pre-Algoman basic rocks are of greater volume and wider extent than they are usually recognized to be, since they are frequently wrongly classed as Keewatin. These basic rocks are represented by the sudburite of the Sudbury area, by the lamprophyres of Cobalt and elsewhere, and apparently by the basic rocks of the townships of Dundonald, Reaume, and others where associated with them are nickeliferous pyrrhotite and chromite.

---

[1] *Ont. Bur. Mines*, XXII, Part II.

TABLE III

PRE-CAMBRIAN EPOCHS OF ONTARIO AND THEIR METAL PRODUCTION

KEWEENAWAN	Epoch, following basic intrusions, of (*a*) silver, cobalt, nickel, and arsenic at Cobalt and elsewhere, (*b*) nickel and copper at Sudbury, and copper elsewhere. Certain gold deposits, not now productive, appear to belong to this epoch.
ANIMIKEAN	Epoch of deposition of "iron formation" as a chemical precipitate.
(ALGOMAN)	Epoch, following granite intrusions, of gold at Porcupine and at many other localities, and of auriferous mispickel. Deposits of galena, zinc blende, fluorite, and other minerals also appear to have been derived from the granites, but some of them were not formed till post pre-Cambrian time. Preceding the intrusion of the Algoman granites, basic intrusives, that appear to be of post-Timiskamian age, gave rise to nickel and titaniferous and non-titaniferous magnetite deposits and chromite.
TIMISKAMIAN	Epoch of minor deposition of "iron formation" as a chemical precipitate.
(LAURENTIAN)	Granite intrusions probably gave rise to ore deposits which have been removed by excessive erosion as is known to be the case with deposits of later origin.
LOGANIAN	
Grenville	Epoch of deposition of extensive "iron formation" as a chemical precipitate among other sediments.
Keewatin	Composed largely of basic volcanic rocks.

Owing to erosion, the sequence of metal deposition shown in Table III is doubtless incomplete.[1] Iron formation occurs in three epochs, the Loganian, Animikean, and Timiskamian, but is of economic importance only in the former two. Certain deposits of titaniferous and non-titaniferous magnetites, not now being worked, are associated with basic intrusives that appear to be of pre-Algoman age. Arsenic occurs in two epochs and has been produced in economic quantities from the rocks of both. In so far as is known, gold occurs in economic quantity only in the Algoman, although small quantities are obtained in refining the copper-nickel ores, and certain auriferous quartz deposits, not now productive, appear to be genetically connected with Keweenawan intrusives. Nickel, as has been shown in the preceding table, was deposited in economic quantities in two epochs. Cobalt, silver, and copper are produced only from deposits of Keweenawan age. Platinum, palladium, mercury, and other metals are found in small quantities with Keweenawan ores. Zinc and lead have been mined in the province, but the age relations of some of the deposits are in doubt.

---

[1] Two or three hundred feet more of erosion would have left comparatively little, for example, of the Cobalt silver deposits, of which, it would seem, more has been eroded than has been mined, or even of the great Mesabi iron deposits of Minnesota.

RELATIVE ECONOMIC IMPORTANCE OF VARIOUS EPOCHS

In Ontario in 1913, the metal production from ore deposits of various pre-Cambrian epochs was as follows: Keweenawan (silver, copper, nickel, cobalt, arsenic), $36,559,688; Algoman (gold), $4,543,690; Keewatin-Grenville (iron and iron ore), $1,195,150. A comparatively small quantity of the nickel and copper credited to the Keweenawan should be assigned to deposits that are associated with basic eruptives of pre-Algoman, and probably post-Timiskamian age, but the value is not definitely known.

While at present in Ontario there is no production from deposits of Animikean or Timiskamian age, millions of tons of iron ore are mined from deposits of these epochs in the state of Michigan.

It is to be understood that the ages given for the deposits do not refer to secondary concentration, as, for instance, in the case of iron ores, but to the epoch in which the metals were first deposited.

In a paper entitled "Metallogenetic Epochs in the Pre-Cambrian of Ontario," presented before the Royal Society of Canada, May, 1915, the authors discuss more fully the age and genetic relations of the ore deposits of the province.